

Distribution and spread of the introduced One-spot Livebearer *Phalloceros caudimaculatus* (Pisces: Poeciliidae) in southwestern Australia

M G Maddern

School of Animal Biology (M092),
Faculty of Natural and Agricultural Sciences,
The University of Western Australia,
35 Stirling Highway, Crawley, Western Australia, 6009, Australia,
✉ mark.maddern@gmail.com

Manuscript received January 2008; accepted July 2008

Abstract

The One-spot Livebearer, *Phalloceros caudimaculatus*, is a neotropical poeciliid maintained as an ornamental fish by hobbyists worldwide. Introduced populations occur in Africa, New Zealand and Australia. This species has been recorded in four Australian states/territories and is now widely dispersed within metropolitan Perth (Swan/Canning catchment) in southwestern Australia. *Phalloceros caudimaculatus* thrives in urban, aquatic habitats (e.g. degraded creeks and storm-water drains) and its range in southwestern Australia is expanding into larger watercourses as a consequence of natural dispersal and human-mediated translocations. *Phalloceros caudimaculatus* has dominated habitats in southwestern and eastern Australia that previously contained high densities of *Gambusia holbrooki*, a highly invasive species with documented impacts on aquatic ecosystems and endemic ichthyofauna. This is of concern as little research has been conducted on the potential ecological impacts of *P. caudimaculatus* in Australia or worldwide. As *P. caudimaculatus* is not commonly kept as an ornamental fish in Australia, the inherent risk of release is lower than that of other popular ornamental fishes. However, the recent establishment of a population in New South Wales indicates that the release of fish, and subsequent colonisation of suitable environments, could occur in other areas of Australia.

Keywords: Australia, Caudo, ecosystem disturbance, freshwater fish, *Gambusia holbrooki*, human-assisted dispersal, introduced species, One-spot Livebearer, *Phalloceros caudimaculatus*, translocation

Introduction

The last three or four decades have seen the establishment of numerous populations of introduced, ornamental fishes in Australia (Arthington & McKenzie 1997; Allen *et al.* 2002). Deliberate, human-mediated translocation is the major vector (Arthington & Mackenzie 1997; Lintermans 2004) with primarily cichlids and poeciliids establishing self-maintaining populations. Many poeciliids are adaptable and tolerant of variable environmental conditions and will thrive in modified and degraded aquatic habitats (Meffe & Snelson 1989). Habitat degradation, including pollution, urban land uses, loss of riparian vegetation and altered hydrological regimes, may disadvantage indigenous species while aiding the establishment of adaptable, introduced fishes (Arthington *et al.* 1990; Moyle & Light 1996).

The One-spot Livebearer or Caudo, *Phalloceros caudimaculatus* (Fig. 1), is a small poeciliid native to fresh/estuarine waters of the central-eastern seaboard of South America, from Brazil (approximately Rio de Janeiro southwards), Argentina, Uruguay and Paraguay (Rosen & Bailey 1963; Almirón *et al.* 2000; López *et al.*

2005). Although one of the first poeciliids maintained by hobbyists (Innes 1946; Kempkes & Schäfer 1998), it is not as popular as other species from this family (e.g. Swordtail *Xiphophorus helleri*, and Guppy *Poecilia reticulata*) due to its drab coloration (McDowall 1999). Like many poeciliids, *P. caudimaculatus* is sexually dimorphic with females and males attaining lengths of 60 and 35mm respectively (Trendall & Johnson 1981). Unlike many tropical ornamental fishes, *P. caudimaculatus* is cold tolerant (Hoedeman 1974; Merrick & Schmid 1984; Maddern 2003), surviving temperatures as low as 5°C. While indigenous South American populations inhabit shallow, vegetated stream margins with low water flow (e.g. Castro & Casatti 1997; Aranha *et al.* 1998; Almirón *et al.* 2000; Eichbaum-Esteves & Lobon 2001; Machado *et al.* 2002; Casatti 2004; Casatti 2005), *P. caudimaculatus* is also known to occupy highly-modified habitats (i.e. streams affected by loss of riparian vegetation and by silt), and estuarine lagoons within its native range (e.g. Penczak *et al.* 1994; Araújo 1998; Garcia *et al.* 2003; Casatti 2004; Lima-Junior *et al.* 2006).

Worldwide, *P. caudimaculatus* is not common as an introduced species and has, at present, only become well established in southwestern Australia. It was introduced to Malawi in Africa (Jubb 1977; Welcomme 1981) and is restricted to the Nswadzi River, a small tributary of the Ruo River. It has not spread into the latter river system



Figure 1. Female *Phalloceros caudimaculatus* (45 mm total length) collected from Lesmurdie Brook in southwestern Australia.

since release in the early 1950s (Denis Tweddle, J.L.B. Smith Institute of Ichthyology, pers. comm.). In New Zealand, this species was recorded in several livestock water troughs near Kamo, in Northland (McDowall 1999), although the current status of this population remains unclear (McDowall 2004). Within Australia, *P. caudimaculatus* has been recorded in four Australian states/territories. Its presence has been noted in outdoor ponds in South Australia (Arthington & Lloyd 1989), and in the Todd River Drainage near Alice Springs, Northern Territory (Unmack 2001). Similarly, the present status of these populations is unknown. In 2002, *P. caudimaculatus* was collected from a series of ponds in Long Reef Golf Course in New South Wales near Sydney (Rowley *et al.* 2005), and despite attempts to eradicate this population using rotenone, it thrives at the latter locality (Rayner & Creese 2006). After the discovery of this population in NSW, *P. caudimaculatus* was immediately listed as a noxious species under the NSW Fisheries Management Act.

This paper documents the historical distribution and range expansion of *P. caudimaculatus* in southwestern Australia. The likelihood of further range expansions through natural dispersal and human-mediated translocations in southwestern Australia, and wider Australia, are also discussed. The further spread of *P. caudimaculatus* is of concern as the species has dominated two urban creeks in southwestern Australia (Maddern 2003), and ornamental ponds in Sydney (Rowley *et al.* 2005), that previously contained large populations of the highly-invasive fish, *Gambusia holbrooki*. *Gambusia holbrooki* is the most abundant introduced poeciliid in Australia (Lintermans 2004) due to wide release as a mosquito biological control agent and it is considered a pest because of deleterious impacts on indigenous fishes and ecosystems (McKay 1978; Merrick & Schmida 1984; Arthington 1991; Gill *et al.* 1999; Allen *et al.* 2002; Morgan *et al.* 2004). At this time it is unknown if *P. caudimaculatus* could have similar impacts. Thus, baseline distribution data are important for determining future range expansions and potential ecological impacts of *P. caudimaculatus*, particularly as such data are often lacking for invasive freshwater fishes in Australia (Koehn & Mackenzie 2004).

Materials and methods

The Western Australian capital, Perth, is located within the Swan/Canning catchment (Fig. 2) which is part of the Southwest Drainage Division of Western Australia. This region has a Mediterranean climate with moderate precipitation, principally during winter (Astill & Lavery 2004). The Swan/Avon River to the east, and the Canning River (which confluences with the Southern/Wungong River) to the south, have catchments of c. 119 000 km² and 20 000 km², respectively (Thurlow *et al.* 1986). Many watercourses in the Swan/Canning system are contained within the Perth metropolitan area, and are therefore anthropogenically modified to varying degrees (Hodgkin 1987; Swan River Trust 2002). Modifications to aquatic habitats may include altered hydrological regimes, presence of non-indigenous vegetation, sedimentation and pollution (nutrient enrichment and solid refuse) (Storey *et al.* 2000; Swan River Trust 2002).

Qualitative sampling by electrofishing (Fig. 3) was undertaken in metropolitan Perth (31°51'–32°14'S, 115°46'–116°13'E) between 2002 and 2006. During sampling, endemic ichthyofauna were recorded and returned whilst *P. caudimaculatus* and *G. holbrooki* were retained if captured. For a greater description of some sample sites within this region see Storey *et al.* (2000) and Maddern (2003). Voucher specimens of *P. caudimaculatus* are lodged with the Western Australian Museum and specimen photographs were submitted to the FISHBASE online database (<http://www.fishbase.org>).

Results and Discussion

Distribution in southwestern Australia

The presence of *P. caudimaculatus* in WA, at two locations in metropolitan Perth (Fig. 2), was noted in published literature almost four decades ago. Griffiths (1972) collected *P. caudimaculatus* (erroneously identified as *Gambusia affinis holbrooki*) at South Perth, with specimens from this location subsequently correctly identified by Trendall & Johnson (1981). This population was observed in an open drain running into ornamental

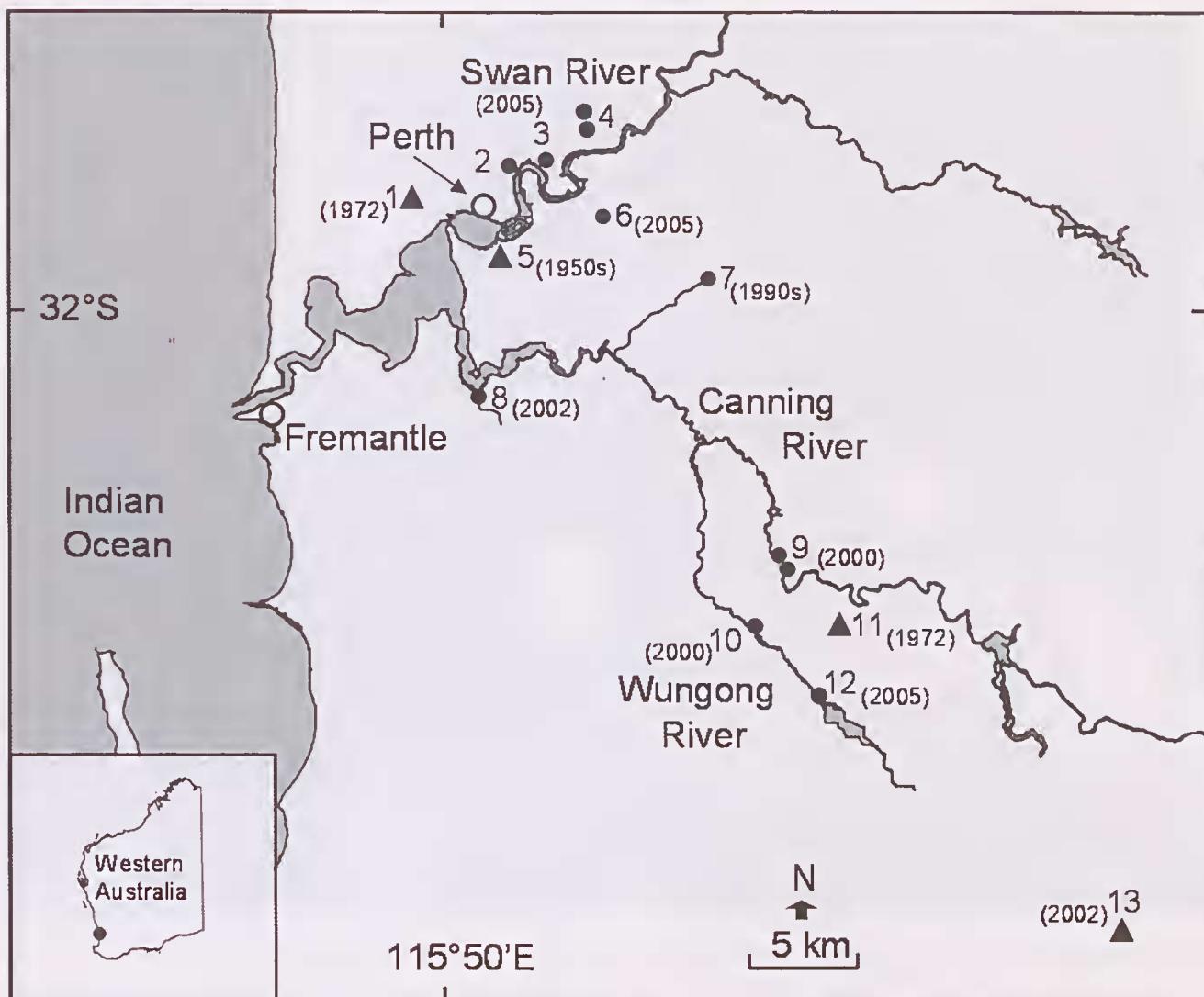


Figure 2. Present (●) and historical (▲) *Phalloceros caudimaculatus* populations within southwestern Australia. Localities (and Perth suburbs) depicted are: 1. Ornamental pond (Subiaco); 2. Banks Reserve drain (East Perth); 3. Mary St drain (Maylands); 4. Mooney St drain (Bayswater); 5. Ellam St drain (South Perth); 6. South Belmont main drain (Belmont); 7. Lesmurdie Brk (Lesmurdie); 8. Bull Crk (Rossmoyne/Bull Creek); 9. Canning River (Kelmscott); 10. Wungong River (Darling Downs); 11. Churchmans Brk (Bedfordale); 12. Wungong Reservoir (Bedfordale); 13. Artificial well, Albany Hwy.

lakes on the Swan River foreshore (Jasper Trendall, Western Australian Fisheries Department, pers. comm.). *Phalloceros caudimaculatus* was observed at South Perth as early as the 1950s, when it was abundant in the drainage system of the foreshore market gardens (Syd Adams, Australian and New Guinea Fish Association, pers. comm.). Recent sampling of drains and ornamental ponds suggests that the species no longer occurs at South Perth, nor at the other location identified by Griffiths (1972), Churchmans Brook (Beatty *et al.* 2003). While the two oldest-known populations in WA appear extinct, *P. caudimaculatus* is now widely dispersed throughout the Swan/Canning system.

Phalloceros caudimaculatus is abundant in Bull Creek and Lesmurdie Brook, both tributaries of the Canning/Wungong system (Fig. 2). It was noted in Bull Creek in 2002 and in Lesmurdie Brook in the 1990s, though the exact date is unclear. Both locations are degraded, urban creeks (Swan River Trust 2002) with *P. caudimaculatus*

particularly common in areas with low water flow and littoral vegetation. Both creeks were originally inhabited by *G. holbrooki* but are now dominated by *P. caudimaculatus*. As part of a related research project, *P. caudimaculatus* was collected monthly from both sites between September 2002 and August 2003. *Gambusia holbrooki* was not collected from Bull Creek during the one-year study period, and only 12 adult *G. holbrooki*, compared with c. 6000 *P. caudimaculatus*, were collected at Lesmurdie Brook. Similar observations were made at Long Reef in New South Wales. Rowley *et al.* (2005) noted that between 1997 and 2002 the community structure shifted from one dominated by *G. holbrooki* to one dominated by *P. caudimaculatus*, with *G. holbrooki* "rare or absent". This apparent displacement of *G. holbrooki* by *P. caudimaculatus* has not been observed, thus far, at other locations in southwestern Australia.

Phalloceros caudimaculatus was collected from a number of sites in the Canning and Wungong Rivers,



Figure 3. Author electrofishing for *Phalloceros caudimaculatus* in the Canning River in southwestern Australia.

and adjacent to the Wungong Reservoir (Fig. 2), in 2005. As observed in other waterways, it thrives in areas with structure and/or emergent vegetation that are protected from stronger water flows. Its presence in these systems was noted by Storey *et al.* (2000), however it was not recorded in prior surveys (e.g. ARL 1988a; ARL 1988b; Pusey *et al.* 1989; Sarti 1994; Storey 1998). The Canning River (Fig. 3) is the largest watercourse containing *P. caudimaculatus* in this region, and it is inhabited not only by *G. holbrooki*, but also by indigenous fishes including *Edelia vittata* (Percichthyidae), *Bostockia porosa* (Percichthyidae) and *Galaxias occidentalis* (Galaxiidae). Although this study indicated that *P. caudimaculatus* has a restricted distribution within the Canning River, the efficacy of the sampling methodology (*i.e.* hand-held electrofisher) is limited in larger river reaches, as also noted by Storey *et al.* (1998). Whereas Storey *et al.* (2000) recorded *G. holbrooki* as dominant in these systems, *P. caudimaculatus* was marginally more abundant than *G. holbrooki* in the Canning River survey sites (Fig. 2) in July 2005. These findings suggest that a more detailed survey is needed to determine the distribution and prevalence of *P. caudimaculatus* in this system.

The most recent range expansion of *P. caudimaculatus* includes major drainage systems connected to the upper Swan River estuary (Fig. 2). *Phalloceros caudimaculatus* occurs in sections of the Belmont and Bayswater main drainage systems, including the Bayswater artificial wetlands. A survey of the Mary St drain in 2005 revealed both *P. caudimaculatus* and *G. holbrooki* to be abundant amongst emergent vegetation, though the latter species was predominant. A further survey in 2006 indicated that *G. holbrooki* still comprised almost 75% of fish present. In the Banks Reserve drain *P. caudimaculatus* was collected with the estuarine species *Leptatherina wallacei* (Atherinidae) and *Mugil cephalus* (Mugilidae). Although the upper estuary was not surveyed, sampling by Hoeksema and Potter (2006) recorded low numbers of *G. holbrooki* only. *Phalloceros caudimaculatus* may have occurred in ornamental ponds in the suburb of Subiaco (Kevin Griffiths, pers. comm.), though it was not recorded at this location, or at an artificial well southwest of Perth identified in Maddern (2003). Thus, *P. caudimaculatus* is widely dispersed throughout the Swan/Canning catchments in metropolitan Perth and occupies drains and highly modified urban creeks as well as larger rivers, such as the Canning River, that contain endemic ichthyofauna.

Risk of further range expansions in Australia

Further range expansions of *P. caudimaculatus* are likely within southwestern Australia and are determined by environmental and anthropogenic factors. The potential for the "natural" dispersal of the species within the Swan/Canning catchment is increased by the winter hydrological regime of this region which is dominated by large, freshwater pulses (Swan River Trust 2002; Astill & Lavery 2004). During these events, fishes may be flushed from drainage systems (e.g. the south Belmont main drain) and tributaries (e.g. Bull Creek and Lesmurdie Brook) downstream into the Swan and Canning Rivers, and into adjacent waterways by flood waters. A population of *P. caudimaculatus* within a section of the Canning River indicates that these larger waterways have already been colonised, though the species' distribution appears to be limited to a small section of this river. Thus, even without further human-mediated translocation of fishes, range expansions within the Swan/Canning system appear highly likely, if not inevitable.

Human-mediated translocation is the major vector responsible for the establishment of nonindigenous ornamental fish populations (Arthington & Mackenzie 1997; Lintermans 2004), however the potential for the release of fish is correlated with the popularity of that species and its abundance among fish hobbyists. Although *P. caudimaculatus* appeared to be a popular aquarium species decades ago (e.g. Innes 1946; Frey 1970; Axelrod *et al.* 1971; Hoedeman 1974) when fewer fish species were available commercially, it was mentioned only once (Sandford 2004) in a brief survey of current aquarium literature aimed at general hobbyists (e.g. Mills 1984; Dawes 1987; Stanislav 1992; Bailey & Dakin 1998; Alderton 2003; Evans 2006). *Phalloceros caudimaculatus* was not observed in commercial aquarium outlets in metropolitan Perth in 2005, although it was available from aquarium shops in the past (Kevin Griffiths, pers. comm.). Corfield *et al.* (2007) listed the importance of *P. caudimaculatus* as a commercial aquarium fish species in Australia as "low". The species is kept by hobbyists in NSW (Rowley *et al.* 2005) and is available commercially in Victoria (Anon 2007). Of course, if it is kept as an ornamental species there is always the possibility of release into the wild, although this risk is likely to be less than for more popular, commonly maintained aquarium species.

Phalloceros caudimaculatus may have been translocated and released as a mosquito biocontrol agent in Australia (Arthington & Blühdorn 1995), and Malawi (Denis Tweddle, J.L.B. Smith Institute of Ichthyology, pers. comm.). Ornamental fishes have been released into dams to control mosquitos in Queensland (McKay 1978), and it is reasonable to speculate that *P. caudimaculatus* may have been maintained in outdoor ponds in South Australia (Arthington & Lloyd 1989) for this purpose. *Phalloceros caudimaculatus* is morphologically similar to *G. holbrooki*, a species that is still known as the "mosquitofish" in the wider community. This name is still common despite the fact that the reputation of *G. holbrooki* for controlling mosquito numbers, by consuming mosquito larvae, is considered erroneous (Merrick & Schmida 1984). *Gambusia holbrooki*

consumes a wide array of dietary items and rarely eats mosquito larvae if other foods are available (Arthington 1989). Similarly, *P. caudimaculatus* is sometimes referred to as "speckled mosquitofish" or "leopard mosquitofish" (Anon 2007). Thus, this misleading nomenclature and the frequent occurrence of the two species in freshwater habitats may prove a motivation for individuals to collect, translocate and release both species for the control of mosquitos. While conducting field research between 2002 and 2006 in metropolitan Perth, anecdotal reports and direct conversations suggested that *P. caudimaculatus* was irregularly collected from two locations for stocking outdoor ponds and private aquaria, and at least once for commercial profit. Thus, as commented by McDowell (2004), there are individuals in the community who consider nonindigenous fish populations as a harvestable resource rather than an environmental concern. Unfortunately, attitudes such as these will ensure the further translocation and release of introduced ornamental fishes such as *P. caudimaculatus*, and perhaps coincidentally, *Gambusia holbrooki* as well. Aided by natural processes of dispersal such as flooding, it is very likely that *P. caudimaculatus* will continue to spread in Western Australia and possibly also in other areas of Australia.

Acknowledgements: Financial assistance was supplied by Land and Water Australia, University of Western Australia, Murdoch University and the Department of Fisheries Western Australia. Thanks to field assistants Stephen Beatty, Samantha Bridgwood, Leah Rheinberger and Jeremy Shaw. Thanks to Andrew Storey and Brenton Knott (School of Animal Biology, UWA), and David Morgan and Howard Gill (Centre for Fish and Fisheries Research, Murdoch University). Gratitude is also expressed to Dianne Webb, Luke van der Leeden and Pete Vanschoub (Curtin University), Rick Roberts (UWA), Syd Adams, Jasper Trendall, Kevin Griffiths and Denis Tweddle for assistance documenting the range expansion of *P. caudimaculatus*.

References

- Alderton D 2003 *The Aquarium Owner's Handbook: Practical Advice on Fish-keeping and Maintenance*. Cassell Illustrated, London.
- Allen G R, Midgley S H & Allen M 2002 *Field Guide to the Freshwater Fishes of Australia*. Western Australian Museum, Perth.
- Almirón A E, García M L, Menni R C, Protogino L C & Solari L C 2000 Fish ecology of a seasonal lowland stream in temperate South America. *Marine and Freshwater Research* 51:265-274.
- Anon 2007 *Phalloceros caudimaculatus* [Internet discussion forum thread]. Available online: <http://aquariumlife.com.au/showthread.php?p=26085> [Accessed 10th September, 2007].
- Aquatic Research Laboratory 1988a Lower Canning River, Stream Fauna Study, Results and Recommendations 1984-1987. Water Authority of Western Australia, Perth.
- Aquatic Research Laboratory 1988b Canning Reservoir catchment, Stream Fauna Study, Results and Recommendations 1984-1987. Water Authority of Western Australia, Perth.
- Aranha J M R, Takeuti D F & Yoshimura T M 1998 Habitat use and food partitioning of the fishes in a coastal stream of Atlantic forest, Brazil. *Revista de Biología Tropical* 46:951-959.
- Araújo F G 1998 Adaptação do índice de integridade biótica usando a comunidade de peixes para o rio Paraíba do Sul. *Revista Brasileira de Biología* 58:547-558.

Arthington A H 1989 Diet of *Gambusia affinis holbrooki*, *Xiphophorus helleri*, *X. maculatus* and *P. reticulata* (Pisces: Poeciliidae) in streams of south-eastern Queensland, Australia. *Asian Fisheries Science* 2:192–212.

Arthington A H 1991 Ecological and genetic impacts of introduced and translocated freshwater fishes in Australia. *Canadian Journal of Fisheries Aquaculture* 48:33–43.

Arthington A H & Blühdorn D R 1995 Improved management of exotic aquatic fauna: R&D for Australian Rivers. Land and Water Resources Research and Development Corporation, Canberra.

Arthington A H, Hamlet S & Blühdorn D R 1990 The role of habitat disturbance in the establishment of introduced warm-water fishes in Australia. In: D A Pollard (ed) *Introduced and Translocated Fishes and their Ecological Effects*. Australian Government Publishing Service, Canberra, 61–66.

Arthington A H & Lloyd L N 1989 Introduced Poeciliids in Australia and New Zealand. In: G K Meffe & F F Snelson Jr (eds) *Ecology and Evolution of Livebearing Fishes*. Prentice Hall, New Jersey, 333–347.

Arthington A H & Mackenzie F 1997 Review of impacts of displaced/introduced fauna associated with inland waters. *State of the Environment Technical Paper Series (Inland Waters)*, Department of the Environment, Canberra.

Astill H L & Lavery P S 2004 Distribution and Abundance of Benthic Macroalgae in the Swan-Canning Estuary, South-Western Australia. *Journal of the Royal Society of Western Australia* 87:9–14.

Axelrod H R, Emmens C W, Sculthorpe D, Vorderwinkler W & Pronek N 1971 *Exotic Tropical Fishes*. T.F.H. Publications, Jersey City.

Bailey M & Dakin N 1998 *The Aquarium Fish Handbook*. New Holland, London.

Beatty S, Morgan D & Gill H 2003 Draft Report of the Fish Resource Survey of Churchman Book Reservoir. Centre for fish and fisheries research, Murdoch University, Perth.

Casatti L 2004 Ichthyofauna of two streams (silted and reference) in the upper Paraná River Basin, southeastern Brazil. *Brazilian Journal of Biology* 64:757–765.

Casatti L 2005 Fish assemblage structure in a first order stream, southeastern Brazil: Longitudinal distribution, seasonality, and microhabitat diversity. *Biota Neotropica* 5(1):75–83.

Castro R M C & Casatti L 1997 The fish fauna from a small forest stream of the upper Paraná River basin, southeastern Brazil. *Ichthyological Exploration of Freshwaters* 7:337–352.

Corfield J, Diggles B, Jubb C, McDowall R M, Moore A, Richards A, Rowe D K, 2007 Draft final report for the project "Review of the impacts of introduced aquarium fish species that have established wild populations in Australia". Australian Government Department of the Environment and Water Resources, Canberra.

Dawes J A 1987 *A Practical Guide to Keeping Freshwater Aquarium Fishes*. Viscount, England.

Eichbaum-Esteves K E & Lobon C J 2001 Composition and trophic structure of a fish community of a clear water Atlantic rainforest stream in southeastern Brazil. *Environmental Biology of Fishes* 62:429–440.

Evans S 2006 *Tropical Aquarium: Setting up and Caring for Freshwater Fish*. New Holland, London.

Frey H 1970 *Illustrated Dictionary of Tropical Fishes*. T.F.H. Publications, Surrey.

Garcia A M, Raseira M B, Vieira J P, Winemiller K O & Grimm A M 2003 Spatiotemporal variation in shallow-water freshwater fish distribution and abundance in a large subtropical coastal lagoon. *Environmental Biology of Fishes* 68:215–228.

Gill H S, Hambleton S J & Morgan D L 1999 Is the Mosquitofish, *Gambusia holbrooki* (Poeciliidae), a major threat to the native freshwater fishes of south-western Australia? In: B Seret & J Y Sire (eds) *Proceedings of the 5th Indo-Pacific Fish Conference*, Noumea. Society of French Ichthyology, Paris, 393–403.

Griffiths K 1972 A Study of the Depredations Incurred among Endemic Australian Fishes by Introduced Fishes with particular reference to *Gambusia affinis*. Teachers higher education certificate, Education Department of Western Australia, Perth.

Hodgkin E P 1987 The hydrology of the Swan River Estuary: salinity the ecological master factor. In: J John (ed) *The Swan River Estuary – Ecology and Management*. Environmental Studies Group, Curtin University of Technology, Perth, Western Australia, 34–44.

Hoedeman J J 1974 *Naturalist's Guide to Freshwater Aquarium Fish*. New York, Sterling.

Hoeksema S D & Potter I C 2006 Diel, seasonal, regional and annual variations in the characteristics of the ichthyofauna of the upper reaches of a large Australian microtidal estuary. *Estuarine, Coastal and Shelf Science* 67:503–520.

Innes W T 1946 *Exotic Aquarium Fishes*. Innes Publishing Company, Philadelphia.

Jubb R A 1977 Notes on exotic fishes introduced into South African inland waters. Part II: Live-bearing tooth-carp. *Piscator* 98:132–134.

Kempkes M & Schäfer F 1998 *All Livebearers and Halfbeaks*. Verlag, Germany.

Koehn J D & Mackenzie R F 2004 Priority management actions for alien freshwater fish species in Australia. *New Zealand Journal of Marine and Freshwater Research* 38:457–472.

Lima-Junior S E, Cardone I B & Goitein R 2006 Fish assemblage structure and aquatic pollution in a Brazilian stream: some limitations of diversity indices and models for environmental impact studies. *Ecology of Freshwater Fish* 15:284–290.

Lintermans M 2004 Human-assisted dispersal of alien freshwater fish in Australia. *New Zealand Journal of Marine and Freshwater Research* 38:481–501.

López H L, Miquelarena A M & Ponte Gómez J 2005 *Biodiversidad y Distribución de la Ictiofauna Mesopotámica*. Miscelánea 14:311–354.

Machado G, Giaretta A A & Facure K G 2002 Reproductive cycle of a population of the Guaru, *Phalloceros caudimaculatus* (Poeciliidae), in Southeastern Brazil. *Studies on Neotropical Fauna and Environment* 37:15–18.

Maddern M G 2003 The distribution, biology and ecological impacts of three introduced freshwater teleosts in Western Australia. Unpublished Honours thesis, Murdoch University, Perth.

McDowall R M 1999 Further feral poeciliid fish in New Zealand fresh waters, with a key to species. *New Zealand Journal of Marine and Freshwater Research* 33:673–682.

McDowall R M 2004 Shoot first, and then ask questions: a look at aquarium fish imports and invasiveness in New Zealand. *New Zealand Journal of Marine and Freshwater Research* 38:503–510.

McKay R J 1978 *The Exotic Freshwater Fishes of Queensland*. Australian National Parks and Wildlife Service, Canberra, ACT.

Meffe G K & Snelson Jr F F 1989 An ecological overview of poeciliid fishes. In: *Ecology and Evolution of Livebearing Fishes (Poeciliidae)* (eds G K Meffe & F F Snelson Jr). Prentice Hall, New Jersey, 13–31.

Merrick J R & Schmida G E 1984 *Australian Freshwater Fishes: Biology and Management*. Griffiths Press Limited, South Australia.

Mills D 1984 *A Fishkeeper's Guide to Community Fishes*. Lansdowne Press, New South Wales.

Morgan D L, Gill H S, Maddern M G & Beatty S J 2004 Distribution and impacts of introduced freshwater fishes in Western Australia. *New Zealand Journal of Marine and Freshwater Research* 38:511–523.

Moyle P B & Light T 1996 Biological invasions of fresh water: Empirical rules and assembly theory. *Biological Conservation* 78:149–161.

Penczak T, Agostinho A & Okada E 1994 Fish diversity and community structure in two small tributaries of the Parana River, Parana state, Brazil. *Hydrobiologia* 294:243–251.

Pusey B T, Storey A W, Davies P M & Edward D H D 1989 Spatial variation in fish communities in two South-Western Australian river systems. *Journal of the Royal Society of Western Australia* 71:69–75.

Rayner T S & Creese R G 2006 A review of rotenone use for the control of non-indigenous fish in Australian fresh waters, and an attempted eradication of the noxious fish, *Phalloceros caudimaculatus*. *New Zealand Journal of Marine and Freshwater Research* 40:477–486.

Rosen D E & Bailey R M 1963 The Poeciliid fishes (Cyprinodontiformes), their structure, and zoogeography and systematics. *Bulletin of the American Museum of Natural History* 126:1–176.

Rowley J J L, Rayner T S & Pyke G H 2005 New records and invasive potential of the poeciliid fish *Phalloceros caudimaculatus*. *New Zealand Journal of Marine and Freshwater Research* 39:1013–1022.

Sandford G 2004 An Illustrated Encyclopaedia of Aquarium Fish. Quantum, London.

Sarti N L 1994 Preliminary Report of the Aquatic Fauna of Bungendore Park and Wungong Brook. Bungendore Park Management Committee.

Stanislav F 1992 The Illustrated Encyclopaedia of Aquarium Fish. Book Company, London.

Storey A W 1998 Fish and Fish Habitat Survey of the Canning River and its Tributaries. Upper Canning Southern Wungong Catchment Team.

Storey A W, Davies P M & Creagh S 2000 Ecological Water Requirements of the Canning River System. Water & Rivers Commission, Perth, Western Australia.

Swan River Trust 2002 Caring for the Canning: A Plan to Revitalise the Canning, Southern and Wungong rivers. Swan River Trust, Perth.

Thurlow B H, Chambers J & Klemm V V 1986 Swan-Canning Estuarine System: Environment, Use and the Future Report 9. Western Australian Waterways Commission, Western Australia.

Unmack P J 2001 Fish persistence and fluvial geomorphology in central Australia. *Journal of Arid Environments* 49:653–669.

Trendall J T & Johnson M S 1981 Identification by anatomy and gel electrophoresis of *Phalloceros caudimaculatus* (Poeciliidae), previously mistaken for *Gambusia affinis holbrooki* (Poeciliidae). *Australian Journal of Marine and Freshwater Research* 32:993–996.

Welcomme R L 1981 Register of international transfers of inland fish species. FAO Fisheries Technical Paper 213:1–120.